HEAT TREATMENT OF LARGE SECTIONS OF TITANIUM ALLOYS

Interim Technical Report No. 1

AD 52135

for

WATERTOWN ARSENAL LABORATORY
Watertown 72, Massachusetts

October 29, 1954

ARMOUR RESEARCH FOUNDATION
of
ILLINOIS INSTITUTE OF TECHNOLOGY
Technology Center
Chicago 16, Illinois

ARF Project No. B 071
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WAL File No. 401/230
Ordnance Project No. TB4-15
Department of the Army Project No. 593-08-021

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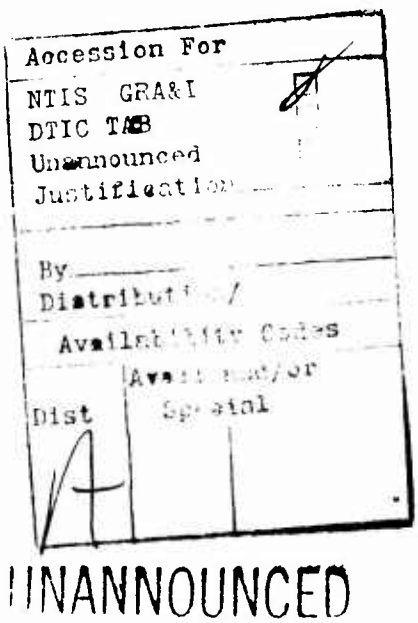

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Date: October 29, 1954

The work reported herein is being performed under the technical supervision of Watertown Arsenal Laboratory.

Chicago Ordnance District.

The objectives of this investigation are directed toward finding a correlation of cooling rates in titanium Jominy bars to the cooling rates in large sections of titanium. The scope of the work planned for the current year includes the following topics:

1. Reproducibility of the Jominy test.
2. Constancy of thermal diffusivity with temperature.
3. Quench severity of several media.
4. Variation of thermal diffusivity with alloy composition.

Authors: A. F. Weinberg and D. W. Levinson

Summary:

In order to correlate the cooling rates in titanium Jominy bars to the cooling rates in large section of titanium, it was necessary to develop an experimental apparatus capable of recording the potentials of many thermocouples at rapid intervals. To record such data, a commutator was adapted to read successively these various potentials and record them on a tape recorder. This report contains the complete description of this

apparatus which is capable of recording potentials of sixteen thermocouples, each at the rate of five times per second.

HEAT TREATMENT OF LARGE SECTIONS OF TITANIUM ALLOYS

I. INTRODUCTION

One of the most important factors in the utilization of manufactured components is the ability for performance (mechanical) specifications to be firmly set and for every piece to meet such specifications. If the properties are to be attained through response to heat treatment, a comparable "ground state" for each piece is mandatory. Quenching, prior to aging anneals, will undoubtedly have to be employed to achieve this condition; air cools following hot working operations or other loosely defined cycles would be unlikely to lead to a reproducible ground state. It is for these reasons that response to quenching must be evaluated for titanium alloys.

As with steel, the end-quench test offers the simplest and most direct method of quantitatively relating anisothermal transformation structure and hardness with cooling histories. The simple test is only useful, however, if the transformation rates of the alloys are sufficiently rapid to permit a broad range of structures to develop over the whole length of the specimen. Fortunately, almost all of the titanium alloys, both in the production and laboratory stages, transform sufficiently rapidly to be amenable to the end-quench type of experiment.

If the end-quench test is used to provide a catalog of transformation behavior, certain basic correlations must be established either experimentally or analytically and certain assumptions must be validated or qualified. The first necessity is a calibration of the cooling histories at each point in the end-quench type specimen. Since such a series of experiments requires considerable expenditure of time and effort, it is desirable that one such calibration serve to describe the behavior of all titanium alloys. This can only be so if thermal diffusivities (thermal conductivity divided by the volume specific heat) are not appreciably affected by alloy composition. This assumption must be validated either directly by measurement of diffusivities of a selection of alloys or by comparing the cooling histories (temperature-time behavior) of a wide selection of alloys at several identical positions in the end-quench test piece.

To facilitate the gathering of experimental cooling data, a multiple potentiometer recording apparatus has been designed and constructed. The purpose of this technical report is to describe this experimental equipment.

II. HIGH SPEED MULTIPLE POTENTIAL RECORDING APPARATUS

Figure 1 shows the recording apparatus designed to record simultaneously the cooling histories along a specimen. A schematic diagram is given in Figure 2. The output of up to 16 thermocouples is brought to the thermocouple terminal strip. The commutation assembly is a rotating copper contact switch serving the function of feeding, in

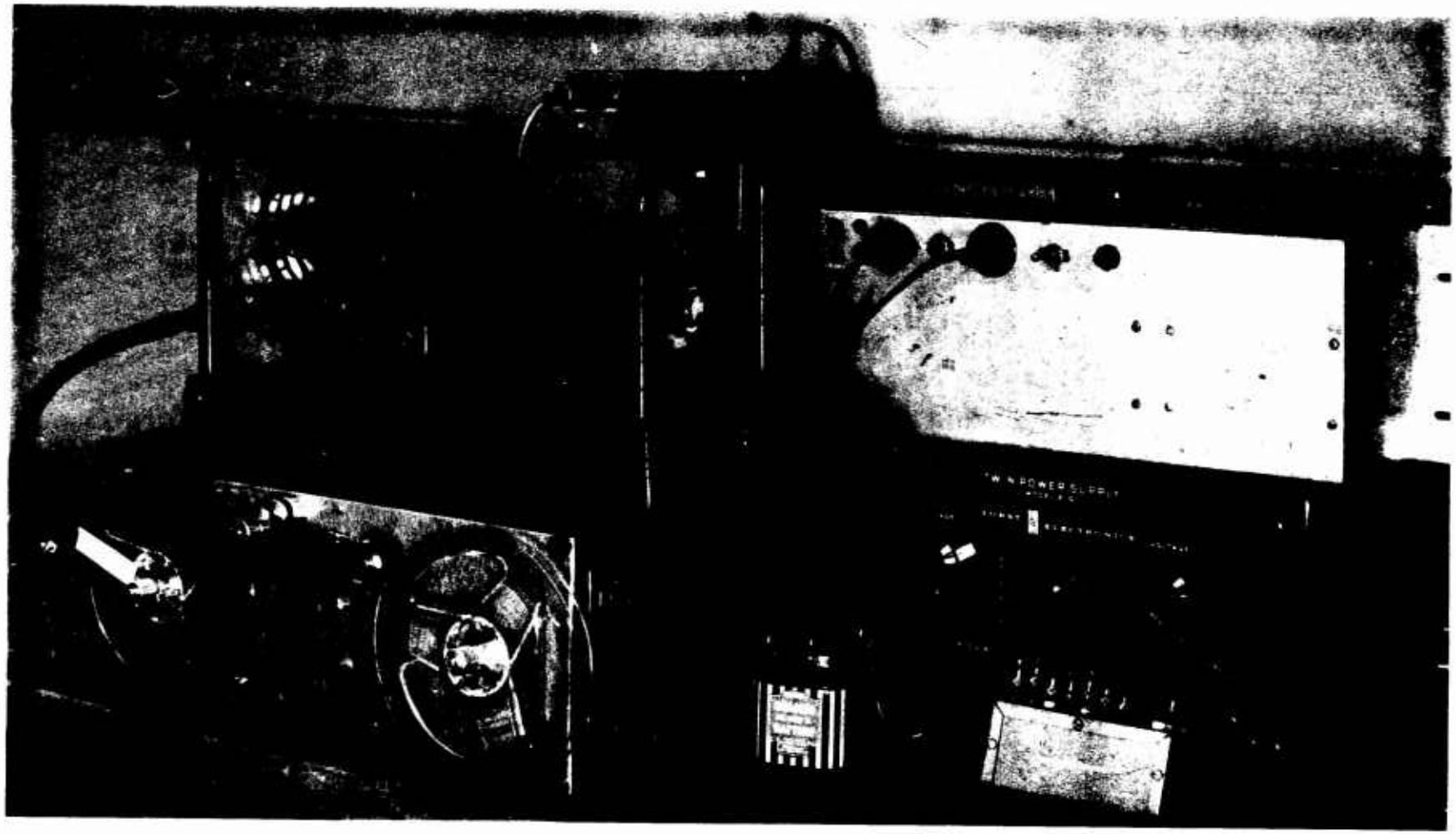

Fig. 1 - Apparatus for Simultaneously Recording the Potentials of 16 Thermocouples.

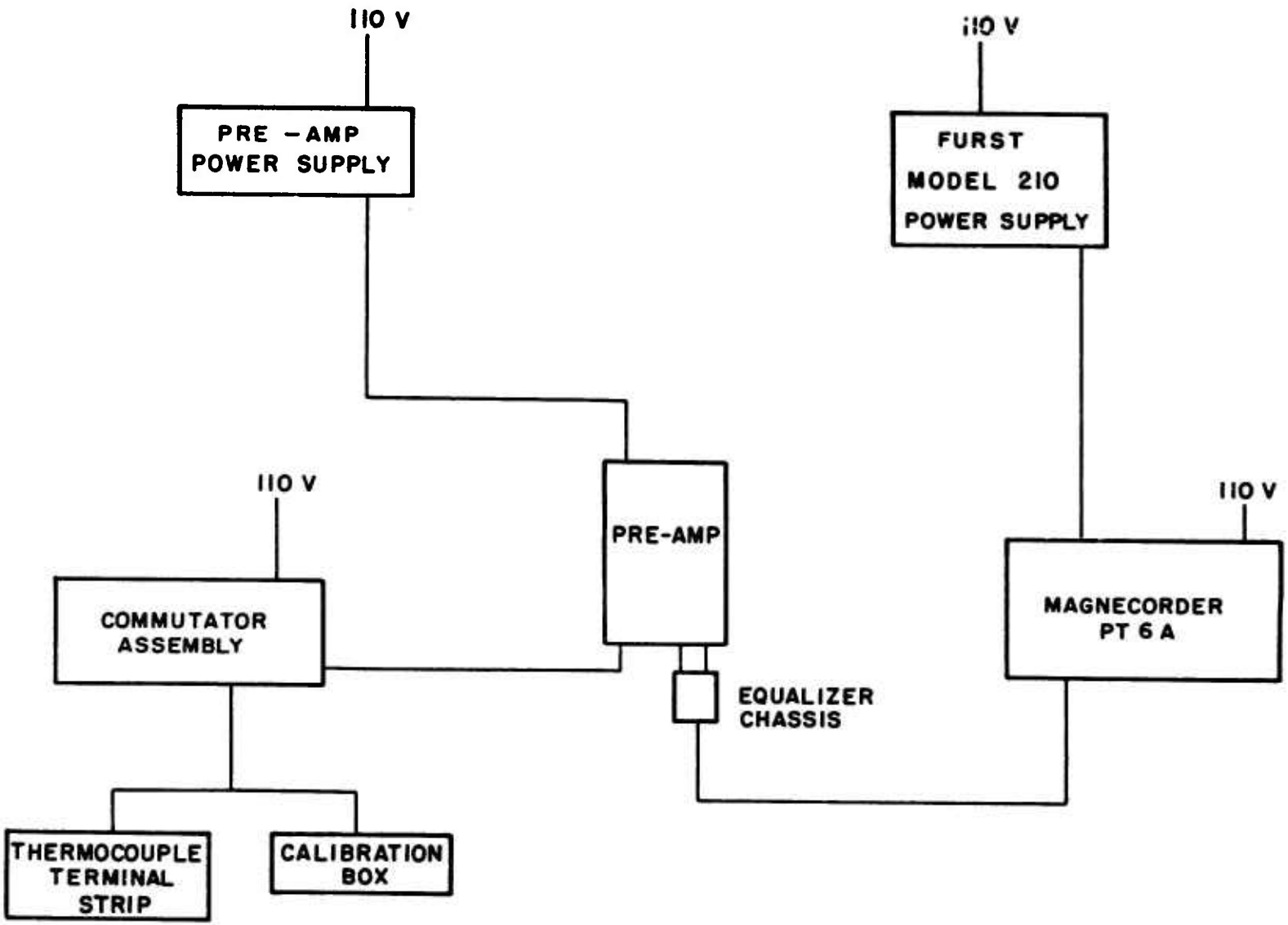

FIG. 2 - BLOCK DIAGRAM OF RECORDER ASSEMBLY

succession, the various thermocouple voltages to the recording apparatus. It is driven by a semi-synchronous motor which is geared to provide precisely 5 revolutions of the switch per second. In this way the output of each thermocouple is recalled five times per second during an entire run. In addition to the 16 contacts required for the thermocouples, three additional contacts are provided to record calibration pulses from a separate chassis shown alongside the thermocouple terminal strip. This is simply a series resistance network and dry cell which provides a selection of voltages between 1 mv and 20 mv. One additional contact is provided for the recording of a negative signal pulse (from the calibration chassis) for the purpose of identifying the beginning of a recording cycle.

The commutation feeds the thermocouple voltages, calibration voltages, and signal voltage in the form of pulsed D.C. to the preamplifier, power for which is provided by the regulated power supply shown. The preamplifier is a direct coupled D.C. amplifier the output of which is flat to beyond 40 KC. The equalizer chassis placed in the output of the preamplifier serves the dual purpose of isolating the recorder input from the static D.C. of the output and providing slight emphasis of the high frequency components of the output signal in order to obtain flat recording characteristics.

The tape recorder itself is a Magnecorder model PTGA. The associated power supply provides operating potentials for the biasing and erasing oscillators.

It is thus possible to record on tape the output of 16 thermocouples with appropriate calibration and signal pulses five times each second continuously during a run up to 30 minutes in length.

The development of this instrument was made feasible only through the previous development, at Armour Research Foundation, of a modulating head which responds to magnetization intensity rather than the rate of change of magnetization. All playback heads currently in common use respond only to the rate of change of magnetization of the tape passing under them. Thus, using ordinary playback techniques it would be mandatory to keep the tape moving at a rate comparable to that at which it moved during recording in the interests of reasonable playback accuracy.

The use of the newly developed modulating head permits the tape to be played back very much more slowly so that readings of any selected pulses may be made at any time during the playback run. The tape may even be stopped to permit reading of the thermocouples or calibration pulses with a potentiometer through a suitable D.C. amplifier.

It is planned to obtain the cooling data from the tape by re-recording through the playback head only desired portions of the run on a direct reading potentiometer, Speedomax "Azar" model, at a slow enough speed to permit the Speedomax to record accurately. This will give a permanent, visual record of the cooling data from which all items pertinent to this program may be obtained.

Two trial runs of the recording assembly have been made using steel rounds as specimens. The results indicate that all of the desired characteristics have been obtained.